



Transportation Synthesis Report

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Variable Speed Limit Signs for Winter Weather

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Transportation Synthesis Reports (TSRs) are brief summaries of currently available information on topics of interest to WisDOT technical staff in highway development, construction and operations. Online and print sources include NCHRP and other TRB programs, AASHTO, the research and practices of other state DOTs, and related academic and industry research.

REQUEST FOR REPORT

Variable speed limit (VSL) systems are Intelligent Transportation Systems that utilize traffic speed and volume detection, weather information, and road surface condition technology to determine appropriate speeds for drivers, and display them on overhead or roadside variable message signs. VSL is being successfully used and/or tested in the U.S., Europe and Australia.¹ In Europe, many variable speed limit signs operate in response to congestion, while others that respond to environmental conditions are being tested.² In the U.S., several states are using VSL to help drivers reduce their speed and risk of error in situations ranging from work zones to winter snows.¹

(¹From: Speed Management Workshop- TRB annual meeting 2000 <http://safety.fhwa.dot.gov/fourthlevel/ppt/vslexamples.ppt>)
(²ENTERPRISE project: Variable Speed Limit <http://enterprise.prog.org/completed/varspeed.htm#anchor131857>)

Wisconsin, a northern state, experiences sudden heavy snows and freezing rain during winter. When this precipitation hits the highways, it reduces traction—sometimes dramatically—until road maintenance crews can respond. The RD&T Program was asked to report on how other transportation agencies in the U.S. and overseas use and operate VSL to help drivers respond promptly and safely to unsafe environmental conditions.

SUMMARY

The Washington State Department of Transportation (WSDOT) is operating a variable message sign and VSL system on I-90 across Snoqualmie Pass in the Cascade Mountains. Currently, a computer recommends the speed limit and an operator confirmation implements it. Ultimately, the system should be capable of automatically determining and posting the safe maximum speed limit for the roadway based on inputs from data stations and weather stations. (See **Washington State**, below.) The New Jersey Turnpike Authority is operating VSL on the New Jersey Turnpike, an urban-rural freeway/high-speed limited access roadway. The system has approximately 120 signs over 238 km and uses inductive loop detectors to collect speed and volume data. The addition of weather-sensing equipment is planned in the near future. The posted speed limit can be reduced for six reasons, including snow, ice and fog. (See **New Jersey**, below.) New Mexico's VSL along I-40 in Albuquerque was dismantled in 1998 when the road was widened from three lanes to five. However, this prototype system was designed for use in any freeway environment. The system covered six km, and for input used precipitation (wet versus dry), traffic speed and light level (day versus dark). The system used a look-up table to generate the posted speed limit. (See **New Mexico**, below.)

Overseas, a recent study by the Technical Research Institute of Finland found that VSL proved to be most effective when adverse weather and road conditions were not easy to detect, such as black ice conditions when the accident risk is highest. (See **Technical Research Institute of Finland**, below.) The Finnish National Road Administration has deployed weather-responsive VSL on at least three roadways. (See **Finnish National Road Administration**, below.) The Netherlands employs a VSL system covering 20 km. System inputs are measured using loop detectors, which are spaced every 0.5 km, and the system has automatic incident detection capabilities. The posted speed is determined by a system control algorithm based on one-minute averages of speed and volume across all lanes. (See **Netherlands**, below.)

WASHINGTON STATE

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The Washington State Department of Transportation (WSDOT) is operating a variable message sign and VSL system on I-90 across Snoqualmie Pass. All equipment is operated through a single operator interface based on PB Farradyne's MIST system, which maintains coordination with the VSL and variable message signs. Information for setting speed limits and for the message signs is gathered from a variety of sources. Wide aperture radar tracks speeds for feedback to the control system. All roadside data collection and control is processed through roadside cabinets. Field equipment communicates by packetized data radio to three mountaintop relay sites. Communications from the mountaintops to the control center are transmitted by microwave. All of this collected information goes to a central computer, which processes the data and determines the "safe speed" for the roadway. This system is monitored from a DOT maintenance office at the pass. Currently, a computer recommends the speed limit and an operator confirmation implements it. Ultimately, the system should be capable of automatically determining and posting the safe maximum speed limit for the roadway on the basis of inputs from data stations and weather stations. The system is designed so that speeds can vary along the corridor, and speed postings for one direction of travel may differ from those for the other direction. Inherent in the system's design is the capability for expansion, and there has been some planning to lengthen the VSL to cover more of I-90. VSL is also being planned for portions of US-2, Stevens Pass, which also crosses the Cascades north of I-90.

Larry says that VSL has been very well received by the maintenance personnel on I-90: "They have told me that VSL and text messages are mostly respected by motorists, and that the motorists perceive the system as a safety enhancement."

The current system was launched several years ago through a project called TravelAid, which partnered WSDOT, the Washington State Transportation Center and FHWA to 1) study the effectiveness of variable message and variable speed limit signs in changing driver behavior, and 2) to help reduce the number and severity of accidents along Snoqualmie Pass. The TravelAid summary report (February 2002) can be purchased at <http://www.ntis.gov/search/product.asp?ABBR=PB2002105731&starDB=GRAHIST>. The full report (December 2001) can be viewed at www.itsdocs.fhwa.dot.gov/jpdocs/repts_te/13610.html

The report presents a number of interesting findings, including:

- One analysis uncovered a wide diversity of speeds reportedly driven in icy conditions, and that motorists drive as fast as the law allows and pay too little attention to prevailing roadway conditions. The installation and use of VSL on the Pass would require motorists to drive at speeds commensurate with current conditions. This should narrow the speed differential between motorists in wet or icy conditions, thus decreasing the potential for accidents and reducing their severity. Without enforcement by the Washington State Patrol, variable speed limits may lose their effectiveness.
- In another study, data were collected from two different locations on I-90. The main location was within the influence of the VSL, and the secondary location was farther west and outside the VSL area. The reduction in mean speed and increase in speed deviation were significantly greater at the VSL site than at the non-VSL site, indicating that the effect of the VSL was to reduce mean speed and increase speed deviation. Also, drivers accelerated faster when exiting the VSL zone when the speed limit was reduced than when it was not. Greater acceleration exiting the zone could possibly increase accident frequency in that area, or negate the safety benefits of lower mean speeds when the speed limit is reduced. More study is needed in this area.

“From the beginning, the roadside equipment varied widely in performance and suitability,” Larry says, “and provided some operational insight that may be of value.

“The full matrix LED variable message signs (VMS) have proved to be the most reliable VMS we've seen up to that time, and they offer immensely improved target value and legibility over other types of signs. The full matrix capability allowed us to display the speed limit in a near traditional format on one end of the sign. Care should be used if the signs are located on a curve to aim at the traffic stream and not along the tangent, because of the narrow broadcast angle of the LEDs.

“The broad beam radar equipment (circa 1994) had a high failure rate. In terms of data they only provided a rolling average speed, and not a speed distribution, therefore the data was of limited value for both logic input and for evaluation. Newer types of radars are being considered for the future. The radar sites were typically spaced at two to five miles, which created an operational issue: the occurrence of low speeds between the sites could go undetected for some time.

“The microwave and 900 MHz radio communications system took some time to aim and tune in the extremely mountainous terrain, but once set up has been highly reliable. The system serves 26 roadside sites.

“The OAC controllers (signal controllers) that were used for a roadside communication handler have proved to be rugged, however they possibly could have been eliminated through the use of multiple port radios allowing MIST to communicate directly with each device. They are also complex to program and have become an impediment to adding new types of devices into the system.”

NEW JERSEY

http://www.itsdocs.fhwa.dot.gov/JPODOCS/REPTS_TE/3_2_1.htm

The system is located on the New Jersey Turnpike—an urban-rural freeway/high-speed limited access roadway. The system has approximately 120 signs over 238 km and uses inductive loop detectors to collect speed and volume data. The addition of weather-sensing equipment is planned in the near future. The posted speed limits are based on average travel speeds and are displayed automatically (manual override is used for lane closures and construction zones). The posted speed limit can be reduced from the normal speed limit (105 km/h, 89 km/h or 80 km/h depending on the milepost location) in eight-km/h increments, to 48 km/h. The posted speed limit can be reduced for six reasons: crashes, congestion, construction, ice, snow and fog. Although system performance has not been formally tested, in the opinion of the Turnpike Authority the system has performed satisfactorily. System performance is monitored in-house to identify any technical problems. The New Jersey Turnpike Authority Operations Department personnel monitor the system 24-hours per day, seven days a week. The speed limit/speed warning and variable message signs are a part of the New Jersey Turnpike's Automatic Traffic Surveillance and Control System (ATSCS). Their function is to alert motorists to any incidents detected by ATSCS that have occurred on the roadway. Incident information is transmitted electronically, via loop detectors in the pavement, to the Authority's Operations Command Center where the sign information is generated and displayed instantaneously to the speed limit/speed warning message boards, alerting motorists of hazardous roadway conditions.

NEW MEXICO

http://www.itsdocs.fhwa.dot.gov/JPODOCS/REPTS_TE/3_2_5.htm

I-40 VSL

The system was installed in March 1989 and dismantled in 1998 when the freeway was widened from three to five lanes. This prototype system was deployed on a busy urban freeway, I-40 in Albuquerque, but was designed for use in any freeway environment (thus its mention here). The system covered six km, with three roadside stations, each consisting of a pair of loop detectors in each lane, with a variable speed sign and hazard warning sign on the right side of the road. As input, the system used traffic speed, light level (day versus dark), and precipitation (wet versus dry). The average traffic speed was computed every 10/s and was smoothed (90 percent old plus 10 percent current). These inputs were obtained by the system using loop detectors for speed, a photocell for light level and a precipitation sensor. The system used a look-up table to generate the posted speed limit. The limit was based on the smoothed average speed plus a constant based on the environmental conditions. Negative constants were used to keep the posted speed below the 89 km/h maximum speed limit cap.

TECHNICAL RESEARCH INSTITUTE OF FINLAND

<http://www.vti.se/nordic/1-02mapp/weather.htm>

Nordic Road & Transport Research: Vol. 1, 2002

“Effects of Weather-Controlled Variable Message Signing on Driver Behavior”

The purpose of the study was to investigate the effects of local and frequently updated information of adverse weather and road conditions on driver behavior. The information was transmitted by several variable message sign types including slippery road condition signs, minimum headway signs, temperature displays and speed limits. The concept of weather-controlled speed limits and displays proved successful. Lowering the speed limit decreased both the mean speed and the variance of speed.

On the weather-controlled road that includes variable speed limits, the control of variable message signs was automatic. The control categories of the road and weather conditions were good, moderate or poor. The effects of lowering the posted speed limit on the weather-controlled road were greater than the effects of the warning and information variable message signs. In winter, the change of the speed limit from 100 km/h to 80 km/h decreased the mean speed by 3.4 km/h, whereas changing the speed limit from 120 km/h to 100 km/h in summer led to a mean decrease of 5.1 km/h. When poor road conditions were difficult to detect, the effect was two km/h higher. Consequently, the system proved to be most effective when adverse weather and road conditions were not easy to detect, such as black ice conditions when the accident risk is highest. The system also decreased the standard deviation of speed. The variable speed limits proved to be more efficient than the warning or information signs because they affected both the mean speed and the speed variance in the desired direction, and the speed effect was much greater. Lowered speed limits due to poor weather and road conditions are on the whole well accepted. In several roadside interviews, drivers recalled the variable fiber optic signs reasonably well. Specifically, 83 to 91 percent of the drivers recalled the posted speed limit and 66 percent recalled the slippery road sign. Ninety-five percent of the drivers indicated that variable speed limits are useful.

The slippery road condition sign is recommended for careful use at critical spots, whereas a system including variable speed limits is recommended for somewhat longer problem sections. The findings suggest that it is extremely important to set the variable speed limits carefully: a sophisticated and error-free data collection and control system is necessary.

FINNISH NATIONAL ROAD ADMINISTRATION

<http://216.239.33.100/search?q=cache:NRUtqUCCAF0J:forum.inet.fi/tielaitos/e18/viking.pdf+between+Lohjanharju+and+the+Turku+Region&hl=en&ie=UTF-8> (Scroll to p. 39)

A trial VSL system was constructed on the 8.5km road section between Lohjanharju and the Turku Region. The fiber-optic VSL signs are controlled automatically, in response to speed recommendations derived from road weather system calculations. Speed limits that change in response to road surface conditions have been used on the single “carriageway” road section between Pyhtää and Kotka since December 1997. The speed limit, 100, 80 or 60km/h, is selected automatically based on information obtained from road weather stations. A total of 66 fiber optic speed limit signs are in use on the 25km-long weather controlled road between Pyhtää and Hamina.

NETHERLANDS

http://www.itsdocs.fhwa.dot.gov/JPODOCS/REPTS_TE/3_2_10.htm

VSL system – A2 Motorway

The VSL system was installed in 1992 on a rural section of the A2 Motorway between Amsterdam and Utrecht, and it is currently active. The system covers 20 km with VSL signs spaced approximately every one km. System inputs are measured using loop detectors, which are spaced every 0.5 km, and the system has automatic incident detection capabilities. The standard posted speed limit is 120 km/h, and the variable posted speeds are 50, 70 and 90 km/h. The posted speed is determined by a system control algorithm based on one-minute averages of speed and volume across all lanes. If an incident is detected, a speed of 50 km/h is displayed. If the speeds are posted with a red circle, they are enforced by photo radar. If posted without the circle, they are advisory.